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Covering Center Programs,
July to September 1986 with
1987 CEEE Events Calendar

June 1987

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INTRODUCTION TO JUNE 1987 ISSUE OF THE CEEE TECHNICAL PROGRESS BULLETIN

This is the sixteenth issue of a quarterly publication providing information on the technical work of the National Bureau of Standards Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Progress Bulletin covers the third quarter of calendar year 1986.

Organization of Bulletin: This issue contains abstracts for all Center papers released for publication by NBS in the quarter and citations and abstracts for Center papers published in the quarter. Entries are arranged by technical topic as identified in the table of contents and alphabetically by first author under each subheading within each topic. Unpublished papers appear under the subheading "Released for Publication". Papers published in the quarter appear under the subheading "Recently Published". Following each abstract is the name and telephone number of the individual to contact for more information on the topic (usually the first author). This issue also includes a calendar of Center conferences and workshops planned for calendar year 1987 and a list of sponsors of the work.

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The metrological products of these programs aid economic growth by promoting equity and efficiency in the marketplace, by removing metrological barriers to improved productivity and innovation, by increasing U. S. competitiveness in international markets through facilitation of compliance with international agreements, and by providing technical bases for the development of voluntary standards for domestic and international trade. These metrological products also aid in the development of rational regulatory policy and promote efficient functioning of technical programs of the Government.

The work of the Center is divided into two major programs: the Semiconductor Technology Program, carried out by the Semiconductor Electronics Division (formerly the Semiconductor Materials and Processes and the Semiconductor Devices and Circuits Divisions) in Gaithersburg, MD, and the Signals and Systems Metrology Program, carried out by the Electrosystems Division in Gaithersburg and the Electromagnetic Fields and Electromagnetic Technology Divisions in Boulder, CO. Key contacts in the Center are given on the back cover; readers are encouraged to contact any of these individuals for further information. To request a subscription or for more information on the Bulletin, write to CEEE Technical Progress Bulletin, National Bureau of Standards, Metrology Building, Room B-358, Gaithersburg, MD 20899 or call (301) 975-2220.

Center sponsors: The Center Programs are sponsored by the National Bureau of Standards and a number of other organizations, in both the Federal and private sectors; these are identified on page 24.

Note on Publication Lists: Guides to earlier as well as recent work are the publication lists covering the work of each division. These lists are revised and reissued on an approximately annual basis and are available from the originating division. The current set is identified in the Additional Information section, page 22.

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SEMICONDUCTOR TECHNOLOGY

Silicon Materials

Released for Publication

Hyland, S.L., Ast, P.G., and Baghdadi, A., **Oxygen Measurements in Thin Ribbon Silicon,** to be published in a Special Issue on Shaped Crystal Growth of the Journal of Crystal Growth.

The oxygen content of thin silicon ribbons grown by the dendritic web technique was measured using a modification of the ASTM method based on Fourier transform infrared spectroscopy. Web silicon was found to have a high oxygen content, ranging from 13 to 19 ppma, calculated using the new ASTM conversion coefficient. The oxygen concentration changed by about 10% along the growth direction of the ribbon. In some samples, a shoulder was detected on the absorption peak associated with interstitial oxygen. A similar shoulder in Czochralski grown material has been variously interpreted in the literature as due to a complex of silicon, oxygen, and vacancies, or to a phase of SiO_2 developed along dislocations in the material. In the case of web silicon, it is not clear which is the correct interpretation of this peak.
[Contact: Aslan Baghdadi, (301) 975-2062]

Thurber, W.R., and Lowney, J.R., **Methods for Accurate Determination of Emission Rate and Trap Concentration with Application to Platinum-Doped Silicon.**

A detailed analysis of junction capacitance was developed which allows one to extract accurate values of emission rate and trap concentration from isothermal transient capacitance measurements. Experiments were performed on silicon diodes doped with platinum. The capacitance-ratio method of determining the emission rate was used to remove the nonexponentiality due to large trap concentration from the capacitance transients. Arrhenius plots of scaled emission rate gave $E_A = 0.2271 \pm 0.0002$ eV for the platinum acceptor level in n-type silicon, and $E_A = 0.3215 \pm 0.0012$ eV for the platinum donor level in p-type silicon. A new method for determining the trap concentration is derived and verified by use of simulations and data. This method involves the subtraction of capacitance values obtained from two transients with the same fill voltage, but different reverse voltages. It is much simpler than methods which require iterative solutions of Poisson's equation and a priori knowledge of the trap energy.
[Contact: W. Robert Thurber, (301) 975-2067]

Analysis Techniques

Recently Published

Bullis, W.M., Watanabe, M., Baghdadi, A., Yue-zhen, L., Scace, R.I., Series, R.W., and Stallhofer, P., **Calibration of Infrared Absorption Measurements of Interstitial Oxygen Concentration in Silicon,** Proceedings of the Silicon Symposium, Boston, Massachusetts, May 4-9, 1986, p. 196.

Many calibration factors for infrared absorption measurements of oxygen in silicon have been reported in the literature and adopted as standard during the past three decades. Reasons for this variability are examined and a new international experiment to establish a universally acceptable value and the reliability to which it can be found are described.
[Contact: Aslan Baghdadi, (301) 975-2062]

Wachnik, R.A., **The Use of Charge Pumping to Characterize Generation by Interface Traps,** IEEE Transactions on Electron Devices, Vol. ED-33, No. 7, pp. 1054-1061 (July 1986).

A small rectangular pulse technique for measuring the charge pumping current has been proposed as a method to character-

Analysis Techniques (cont'd.)

ize interface traps near mid-gap. It is shown theoretically and experimentally that the small rectangular pulse technique can be used to predict the surface generation current measured on a metal oxide-semiconductor field-effect transistor or a gated diode. This new technique has the advantage that the measured current is at least 10 to 100 times larger than the surface generation current.
[Contact: Gary P. Carver, (301) 975-2091]

Dimensional Metrology

Recently Published

Postek, M.T., **Electron Detection Modes and Their Relation to Linewidth Measurement in the Scanning Electron Microscope**, Proceedings of the 44th Annual Meeting of the Electron Microscopy Society of America, Albuquerque, New Mexico, August 10-15, 1986, pp. 646-649.

The basic premise underlying the use of the scanning electron microscope for linewidth measurement for semiconductor research and production applications is that the video image acquired, displayed, and ultimately measured reflects accurately the structure of interest. This paper demonstrates that depending upon the mode of electron detection (secondary, backscattered, or converted backscattered secondary electrons) and accelerating voltage used to image and measure the structure of interest, a variety of results can be obtained. The reasons for these differences are discussed relative to the coupling of this type of work with electron beam/sample interaction modeling to enable the acquisition of more precise linewidth measurements.
[Contact: Michael T. Postek, (301) 975-2299]

Integrated Circuit Test Structures

Recently Published

Cresswell, M.W., Coleman, E.S., Pessall, N., Linholm, L.W., and Radack, D.J., **An Expert System Approach to Enhanced VLSI/VHSIC Process Development**, to be published in the Proceedings of the Government Microcircuits Applications Conference (GOMAC), San Diego, California, November 11-13, 1986.

This paper describes the use of an expert system and specially designed microelectronic test structures for assisting in the evaluation of a developmental submicron wafer fabrication process. The method of compiling the knowledge base is described and examples of test structure parameter extraction and automatic diagnostic characterization of the fabrication process are presented.
[Contact: Loren W. Linholm, (301) 975-2052]

Recently Published

Cresswell, M.W., Pessall, N., Linholm, L.W., and Radack, D.J., **The Use of Artificial Intelligence and Microelectronic Test Structures for Evaluation and Yield Enhancement of Microelectronic Interconnect Systems**, Proceedings of the Third International IEEE Conference on VLSI Multilevel Interconnection, Santa Clara, California, June 9-11, 1986, pp. 331-340.

A major factor limiting the production and performance of high-density VLSI integrated circuits is the fabrication of reliable interconnect systems. Properly designed microelectronic test structures and appropriate test methods can be used to characterize the processes used to fabricate these systems. However, the computer-controlled testing of comprehensive process evaluation and diagnosis structures often results in large quantities of data which cannot be readily or effectively interpreted by the user. As a result, important features of the data are often overlooked or not considered in the evaluation of the fabrication processes. This paper describes an expert system for assisting

IC Test Structures (cont'd.)

the user to interpret test results associated with fabricating selected aspects of VLSI interconnect systems.
[Contact: Loren W. Linholm, (301) 975-2052]

Device Physics and Modeling

Released for Publication

Albers, J., **Semiconductor Measurement Technology: Results of the Monte Carlo Calculation of One- and Two-Dimensional Distributions of Particles and Damage: Ion Implanted Dopants in Silicon,** to be published as NBS Special Publication 400-79.

The TRansport of Ions in Matter (TRIM) Monte Carlo code was used to calculate the two-dimensional distributions of particles, primary damage, and electronic and nuclear energy loss for implantation of a line beam source into silicon targets. Approximate two-dimensional distributions of the Frenkel pairs (vacancy-interstitial) created by the primary displacement damage of the target atoms were calculated by means of the Kinchin-Pease equation. These particle, damage, and energy loss distributions allowed for the calculation of the one-dimensional distributions of these quantities for implantation into unmasked targets. A superposition technique was used to construct the two-dimensional particle and approximate Frenkel pair distributions for implantation past a mask edge. The energetic ions used in the calculations were in two groups: those used as intentional dopants in silicon device fabrication and those which either limited lifetime or acted as gettering sites. The one-dimensional particle distributions as well as the lateral particle profile at maximum lateral penetration under the mask edge were parameterized by means of standard polynomial fitting techniques.
[Contact: John Albers, (301) 975-2075]

Geist, J., **Recent Improvements in Radiometric Accuracy Based on New Detector Technology.**

Until recently, the best accuracy achievable in the measurement of radiometric properties was limited by the accuracy of the ultimate radiometric standard to which the measurement could be traced. Since about 1980, however, there have been such dramatic improvements in the accuracy of detector-based standards that this is no longer the case. These new radiometric standards are briefly reviewed in this paper, with emphasis on the intercomparisons that demonstrate their accuracy.
[Contact: Jon Geist, (301) 975-2066]

Marchiando, J.F., and Albers, J., **Effects of Ion-Implantation Damage on Two-Dimensional Boron Diffusion in Silicon.**

Well-defined control of boron implanted in silicon during a high-temperature short-time anneal is important in calculation of shallow p-n junction profiles in metal oxide-semiconductor field-effect transistors (MOSFETs). During an anneal, boron may exhibit enhanced diffusion lasting about a second. Here, displacement damage is removed largely by release and condensation of single vacancies, which enhance the boron diffusion via the charged vacancy mechanism. Model 2-D distributions of boron and displacement damage implanted near a mask edge are used to calculate the redistribution of boron resulting from a seven-second anneal. Boron redistributes further into the bulk, while leaving the channel length unaffected. The redistribution agrees favorably with that reported in the literature.
[Contact: Jay F. Marchiando, (301) 975-2088]

Recently Published

Bennett, H.S., **Band Structure and Density of States Changes in Heavily Doped Silicon,** Journal of Applied Physics, Vol. 59, No. 8, pp. 2837-2844 (April 15, 1986).

Device Physics and Modeling (cont'd.)

The Klauder self-energy method is applied to calculating the effects of one-body interactions among the dopant ions and the carriers in heavily doped silicon at 300 K. Many-body interactions of exchange energy for majority carriers and of correlation energy for minority carriers are estimated by interpretation of optical absorption measurements and by calculations based on degenerate theory. When densities exceed 5×10^{19} cm^{-3}, one-body and many-body terms become of the same order of magnitude and should be included in calculations of band-structure changes and of properties such as carrier transport which depend on the density of states.
[Contact: Herbert S. Bennett, (301) 975-2079]

Bennett, H.S., **Device Physics for Modeling GaAs Bipolar Transistors**, Proceedings of the Semiconductor Research Corporation Conference on Bipolar Technology, Tempe, Arizona, April 24-25, 1986, S. A. Abbas, Ed., Paper II.17.

The accuracy and reliability of predictions from numerical simulations of advanced bipolar transistors depend on model input parameters. These parameters include the variations with doping and carrier concentrations in both n-type and p-type material of 1) the valence and conduction band edges, 2) the effective intrinsic carrier concentrations, 3) the minority carrier mobilities, and 4) the minority carrier lifetimes. This paper contains a summary of recent advances in device physics for modeling silicon bipolar transistors with submicrometer dimensions and high concentrations of dopant ions and carriers. It also contains preliminary results in device physics for modeling those regions of GaAs bipolar transistors which have high concentrations of either dopant ions or carriers. The latter results are based on lessons learned from modeling advanced silicon bipolar devices.
[Contact: Herbert S. Bennett, (301) 975-2079]

Bennett, H.S., Gaitan, M., Roitman, P., Russell, T.J., and Suehle, J.S., **Modeling MOS Capacitors to Extract Si-SiO_2 Interface Trap Densities in the Presence of Arbitrary Silicon Doping Profiles**, IEEE Transactions on Electron Devices, Vol. ED-33, No. 6, pp. 759-765 (June 1986).

The MOS capacitor model in SEDAN has been modified to include the effects of an energy-dependent Si-SiO_2 interface trap density and arbitrary silicon substrate doping profiles. These modifications have been used to calculate the quasi-static C-V characteristics of MOS capacitors and to compare them with those measured by the Kuhn technique for as-received and for gamma-irradiated p-well and n-type silicon MOS capacitors. The average substrate doping is obtained from high-frequency C-V curves. For the n-type substrate, the dopant redistribution was estimated with SUPREM II. Experimental and theoretical C-V curves were made to agree by varying the voltage offset due to fixed oxide charge and both the magnitude and the energy distribution of interface trapped charge. The distributions of interface traps which gave the best fits between experiment and theory have peaks near mid gap for the p-well and n-type silicon MOS capacitors.
[Contact: Herbert S. Bennett, (301) 975-2079]

Berning, D.W., and Blackburn, D.L., **Power MOSFET Failure During Turn-Off: The Effect of Forward Biasing the Drain-Source Diode**, Conference Proceedings of the 1986 IEEE Industrial Applications Society Annual Meeting, Denver, Colorado, September 25-October 3, 1986, pp. 335-339.

The effects on the turn-off failure of power metal oxide-semiconductor field-effect transistors (MOSFETs) which result from forward biasing the intrinsic drain-source diode immediately prior to

Device Physics and Modeling (cont'd.)

turn-off are discussed. A nondestructive test circuit is used to measure the turn-off characteristics of individual devices under a variety of conditions. It is shown that the drain voltage at which the device fails decreases as either the diode forward current or the reverse recovery current is increased. If the diode is forward biased, the voltage at failure can be less than one-half of the voltage at which the device fails if the diode has not been forward biased (and often less than one-half the manufacturer-rated voltage capability for the device). Also, if turn-off of the MOSFET is attempted with the diode conducting, the device loses its fast turn-off capability due to charge storage effects. A parallel resonant power converter circuit is employed to demonstrate how the intrinsic drain-source diode may and may not be used safely in practical applications.
[Contact: David W. Berning, (301) 975-2069]

Radiation Effects

Released for Publication

Hefner, A.R., Blackburn, D.L., and Galloway, K.F., **The Effect of Neutrons on the Characteristics of the Insulated Gate Bipolar Transistor (IGBT)**, to be published in the IEEE Transactions on Nuclear Science.

The effects of neutrons on the operating characteristics of Insulated Gate Bipolar Transistors (IGBT) are described. Experimental results are presented for devices that have been irradiated up to a fluence of 10^{13} neutrons/cm^2, and an analytical model is presented which explains the observed effects. It is found that with increasing neutron fluence, the on-state voltage increases, the switching time decreases, and the saturation current decreases. For the range of fluences studied, the observed effects result from a reduction in minority carrier lifetime in the IGBT and not from changes in the effective dopant density. The effects of neutrons on the IGBT are compared with their known effects on power MOSFETs, and it is shown that the IGBT characteristics begin to degrade at a fluence that is an order of magnitude less than the fluence at which the power MOSFET begins to degrade. At high fluences, the IGBT takes on the characteristics of a power MOSFET.
[Contact: Allen R. Hefner, (301) 975-2071]

Russell, T.J., Bennett, H.S., Gaitan, M., Suehle, J.S., and Roitman, P., **Correlation Between CMOS Transistor and Capacitor Measurements of Interface Trap Spectra**, to be published in IEEE Transactions on Nuclear Science.

The radiation-induced change in the energy spectra of SiO_2-Si interface traps as determined using 1) the charge-pumping and weak-inversion techniques on CMOS transistors and 2) using the quasi-static capacitance-voltage and detailed model techniques on complementary metal oxide semiconductor (CMOS) capacitors are compared. The interface trap spectra determined from these measurements are in good quantitative agreement over most of the band gap for the range of densities of traps approximately 10^{10} to 10^{12} cm^{-1} eV^{-1}.
[Contact: Thomas J. Russell, (301) 975-2073]

Singh, G., Galloway, K.F., and Russell, T.J., **Radiation-Induced Interface Traps in Power MOSFETs**, to be published in IEEE Transactions on Nuclear Science.

Methods for estimating values of radiation-induced interface trapped charge from the current-voltage (I-V) characteristics of metal oxide-semiconductor field-effect transistors (MOSFETs) are described and applied to commercially available power MOSFETs. The power MOSFETS show severe degradation on radiation exposure with the effects of positive oxide trapped charge dominating;

Radiation Effects (cont'd.)

however, interface trap buildup is significant. The results are compared to experimental measurements available on other technologies.
[Contact: Thomas J. Russell, (301) 975-2073]

Insulators and Interfaces

Recently Published

Candela, G.A., Chandler-Horowitz, D., Novotny, D.B., Vorburger, T., and Giauque, G.H., **Film Thickness and Refractive Index Standard Reference Material Calibrated by Ellipsometry and Profilometry**, Proc. SPIE - The International Society for Optical Engineering, Vol. 661, pp. 402-407, SPIE, P.O. Box 20, Bellingham, WA 98227 (1986) [conference Quebec, Canada, June 2-6, 1986].

A Standard Reference Material (SRM) has been designed and fabricated, and will be calibrated for thickness and refractive index using a highly accurate ellipsometer. The SRM consists of a three-inch diameter silicon wafer with a silicon dioxide film of uniform thickness. The design and preparation of the SRM is discussed and the ellipsometric measurement results and their comparisons with stylus profilometry are presented, along with an analysis of the precision of the measurements. The ellipsometric accuracy depends upon the wafer oxide film, the model that represents the film-interface-substrate system, and the methods used to make the measurements. Use of both correct sample preparation and correct model is important in order to obtain high accuracy for comparisons of optical thickness as determined by the ellipsometer and mechanical thickness as determined by the stylus profilometer. This SRM will be available initially in three nominal oxide film thicknesses of 50, 100, and 200 nm. The SRM can be used to calibrate many different optical and mechanical thickness monitoring instruments as well as the ellipsometer for which it was specifically designed.
[Contact: George A. Candela, (301) 975-2086]

Mazer, J.A., and Ehrstein, J.R., **Effect of Sintering on the Sheet Resistance Directly Under an Aluminum/Silicon Ohmic Contact**, Extended Abstracts of the Electrochemical Society 169th Meeting, Boston, Massachusetts, May 4-9, 1986, pp. 396-397.

Van der Pauw-type measurements with a specially designed test structure and spreading resistance measurements indicate that the sheet resistance directly under a sintered 1% Si-Al/Si ohmic contact is lower than the sheet resistance of the diffused layer away from the contact. These results agree with transmission-line calculations made with measurements from six-terminal Kelvin test structures, and allow an improved calculation of the circuit-loading (or front-contact) resistance.
[Contact: James R. Ehrstein, (301) 975-2060]

Mountain, D.J., Russell, T.J., and Galloway, K.F., **Effect of Post-Oxidation Anneal on Electrical Characterization of Thin Oxides**, Extended Abstracts of the Electrochemical Society 169th Meeting, Boston, Massachusetts, May 4-9, 1986, pp. 382-383.

The effect of pre- and post-oxidation treatments on thin oxide electrical characteristics was examined. Pre-oxidation clean and post-oxidation anneal (POA) times and ambients were varied. Three POA times and two gases (argon and nitrogen) were compared. Flatband voltages, oxide breakdown fields, and interface trap densities were measured for thin (20-nm) oxides. Interface trap densities were measured using the charge-pumping technique. Data indicate an optimum process can be designed. A sacrificial oxidation cleaning sequence and a long (120-min) POA in nitrogen gave the oxide with the best electrical characteristics.

Insulators and Interfaces (cont'd.)

[Contact: Thomas J. Russell, (301) 975-2073]

Other Semiconductor Topics

Released for Publication

Bouldin, C.E., Forman, R.A., Bell, M.I., Donovan, E.P., and Hubler, G.K., **EXAFS Measurements of Ion and Implanted Amorphous Surface Layers.**

Extended x-ray-absorption fine-structure (EXAFS) measurements of ion-damaged amorphous Ge (a-Ge) show that low-temperature annealing causes a structural relaxation in the as-implanted a-Ge. It is found that there is a sharpening of the first shell in the radial distribution but no change occurs in the first-shell distance or coordination number. No higher shells in the radial distribution are observed either before or after annealing, indicating that these shells remain highly disordered. The observed structural relaxation is an amorphous-amorphous transition; no nucleation of microcrystals takes place. EXAFS measurements are made using conversion electron detection, which is essentially total electron yield detection in ambient conditions, allowing the EXAFS measurements to be near-surface sensitive with a sampling depth of 600 to 800 Å.
[Contact: Charles E. Bouldin, (301) 975-2946]

Novotny, D.B., **Measurement of the Separation Distance in Contact and Proximity Lithography**, to be published in the Journal of the Electrochemical Society.

A method is presented for measuring the separation distance between the substrate surface and the mask surface in contact and proximity optical lithography. This method utilizes the analysis of the Fresnel diffraction pattern produced by a slit aperture in the mask and physically replicated in the photoresist. From the analysis, the image distance producing the observed Fresnel diffraction pattern is obtained and is used to calculate the separation distance. The conditions for the application of this method are presented and an easy method for computer-generation of the Fresnel diffraction patterns is described. A simplified method for estimating the separation distance from the number of diffraction pattern peaks and valleys is also given. Results are presented showing that a finite separation distance may exist in hard "contact" lithography and that this measurement method is applicable from distances from near zero to 20 or more micrometers.
[Contact: Donald B. Novotny, (301) 975-2699]

Recently Published

Dodge, M., **Refractive Index**, CRC Handbook of Laser Science and Technology, Vol. IV, Optical Materials: Part 2, M. J. Weber, Ed. (CRC Press, Boca Raton, Florida, 1986), pp. 21-47.

This section defines refractive index, gives the general form of the Cauchy, Sellmeier, and Hertzberger dispersion equations, and discusses the environmental factors that must be considered in the determination and use of refractive index values for a particular material. Tables are included that give the refractive index and the temperature coefficient of refractive index for crystals that are of particular interest for the fabrication of optical components to be used in laser systems.

Dispersion equations and equation parameters are also given for some of the materials.
[Contact: Marilyn Dodge, (301) 975-2386]

Ma, Y., Stern, E.A., and Bouldin, C.E., **The Structural Unit in Icosahedral MnAlSi and MnAl**, Physics Review Letters, Vol. 57, No. 13, pp. 1611-1614 (Sept. 29, 1986).

Extended x-ray-absorption fine-structure

Other Semiconductor Topics

measurements were made on icosahedral MnAl and MnSiAl, and on the periodic standards α-phase of MnSiAl and orthorhombic phase of $MnAl_6$. Experimental evidence is presented that a cage of Mn atoms at the vertices of an icosahedron is the structural unit in the icosahedral MnSiAl and MnAl phases. The connections among these icosahedral units and between them and the Al atoms are different in the icosahedral phases and in the α-phase. As in the α-phase, the Mn icosahedra do not share vertices in the icosahedral phases; i.e., they are separated from one another. It is suggested that the i-phase grows by randomly nucleating together Mn icosahedra along their 20 threefold directions, as allowed by local steric constraints.
[Contact: Charles E. Bouldin, (301) 975-2046]

FAST SIGNAL ACQUISITION, PROCESSING, & TRANSMISSION

Waveform Metrology

Released for Publication

Schoenwetter, H.K., **Design and Characterization of a Programmable Step Generator with Very Fast Settling Performance**, Summary to be published in CPEM 86 Digest, 1986 Conference on Precision Electromagnetic Measurements, NBS, Gaithersburg, Maryland, June 23-27, 1986. Full-length versions of papers presented at CPEM 86 are to be published in a special (CPEM 86 Proceedings) issue of the IEEE Transactions on Instrumentation and Measurement.

A pulse generator for testing the step-response of waveform recorders is described. The initial and final levels of voltage steps are each programmable within the range of ±1 V for a 50-Ω termination. Voltage steps within this range settle to within ±0.2% and ±0.1% of full-scale range (FSR) in approximately 4 ns and 6 ns, respectively. The 10 to 90% transition duration (T_R) is approximately 1.7 ns.
[Contact: Howard K. Schoenwetter, (301) 975-2414]

Souders, T.M., and Flach, D.R., **Accurate Frequency Response Determinations from Discrete Step Response Data.**

An approach is presented for quickly obtaining the complex frequency response of a system from sampled step response data. Digital signal processing techniques are used extensively. An analysis of errors resulting from sampling, quantization, first differencing, and record length is included.
[Contact: T. Michael Souders, (301) 975-2406]

Cryoelectronic Metrology

Released for Publication

Kautz, R.L., **Global Stability of Phase Lock Near Chaotic Crisis in the RF-Biased Josephson Junction.**

The global stability of phase lock in the radio-frequency-biased Josephson junction is studied through digital simulations. Global stability is determined by calculating the lifetime of the phase-locked state in the presence of thermal noise. This lifetime, the mean time required for thermal noise to induce a 2π phase slip, increases exponentially with inverse temperature in the limit of low temperatures, and the low-temperature asymptote can be parameterized in terms of an activation energy ε and an attempt time τ_o. The activation energy is a useful measure of global stability for both periodic and chaotic phase-locked states. The behavior of ε and τ_o is studied over a range of critical current densities which take the system from a region of harmonic motion through a period-doubling cascade and into a region of phase-locked chaotic behavior which is ended by a chaotic crisis. At the crisis point, the activation energy goes to zero and the attempt time goes to

Cryoelectronic Metrology (cont'd.)

infinity. The results are used to determine the optimum critical current density for series-array voltage standards.
[Contact: Richard L. Kautz, (303) 497-3391 or -3988]

Raisanen, A.V., Crete, D.G., Richards, P.L., and Lloyd, F.L., **Low Noise SIS Mixer with Gain for 80-115 GHz.**

Several superconductor-insulator-superconductor (SIS) quasiparticle mixers have been designed and tested for the frequency range from 80 to 115 GHz. The sliding backshort is the only adjustable radio-frequency (rf) tuning element, simplifying optimization of mixer performance compared to designs previously described in the literature of radio astronomy receivers. The rf filter reactance is used as a fixed rf-matching element. A mixer which uses a single $2 \times 2\ \mu m^2$ Pb-alloy junction in a 1/4-height waveguide mount has a coupled conversion gain of $G_M(DSB) = 2.6 \pm 0.5$ dB with an associated noise temperature of $T_M(DSB) = 16.4 \pm 1.8$ K at the best double-sideband (DSB) operation point. The receiver noise temperature $T_R(DSB)$ is 27.5 ± 0.8 K. This mixer provides single-sideband (SSB) receiver noise temperatures below 50 K over the frequency range from 91 to 96 GHz, the minimum being $T_R(SSB) = 44 \pm 4$ K. These SSB values are calculated from the DSB measurements.
[Contact: Frances L. Lloyd, (303) 497-3254 or -3988]

Recently Published

Hamilton, C.A., Kautz, R.L., and Lloyd, F.L., **The NBS Josephson Array voltage Standard**, CPEM 86 Digest, 1986 Conference on Precision Electromagnetic Measurements, Gaithersburg, Maryland, June 23-27, 1986, pp. 108-109.

It has been realized for many years that the accuracy of Josephson voltage standards can be substantially improved by using many junctions in series to generate a large voltage. A simple series extension of the single junction standard requires individual control of the bias current, for example, for each junction of 100 mV using 20 junctions. In 1977 Levinsen et al. suggested a method to avoid the multiple bias problem by using constant-voltage steps which cross the zero-current axis of the plot of junction current as a function of voltage (I-V curve). This allows a large array of junctions to share a common current bias at or near zero. With an array of 1000 or more junctions, a quantized voltage of 1 V is possible. After nearly ten years of effort, the problems of fabrication, stability, and radio-frequency energy distribution are largely solved and Josephson standards at the 1-V level are a reality. This paper reviews the design and operation of series array voltage standards and describes the efforts at NBS to engineer a versatile, reliable, and easily used voltage standard system.
[Contact: Clark A. Hamilton, (303) 497-3740]

Antenna Metrology

Released for Publication

Baird, R.C., Daywitt, W.C., Newell, A.C., Perera, S., Repjar, A.G., Wait, D.F., and Estin, A.J., **Calibration Requirements for EHF Satellite Communication Systems**, to be published as NBSIR 86-3058.

The calibration and measurement support requirements of millimeter-wave satellite systems such as MILSTAR have been investigated. Needs for measurements on satellite systems are reviewed. An overview of the various means available for calibrating antenna gain, one of the key parameters that need to be measured accurately, is presented. Essentially three new measurement problems arise because of operating in the upper super-high frequency (3 to 30 GHz) and extremely high frequency (EHF, 30 GHz to quasi-optical) ranges. First, without

Antenna Metrology (cont'd.)

adequate methods to measure the atmospheric loss, the accuracy of effective isotropic radiated power (EIRP) measurements in the 20 to 45 GHz range can be no better than 0.5 dB to 3 dB (depending on frequency and antenna elevation angle), which is inadequate for MILSTAR requirements. Second, standards and measurement support services are not presently available from the National Bureau of Standards and are needed to support millimeter-wave antenna gain and thermal noise measurements. Third, if the sun and/or moon are to be used as a basis for measuring the earth terminal figure of merit G/T, earth terminal antenna gain, or satellite EIRP in the millimeter region, we need appropriate characterization of these sources in that region.
[Contact: Ramon C. Baird, (303) 497-3301]

Noise Metrology

Recently Published

Daywitt, W.C., **10-60 GHz G/T, Measurements Using the Sun as a Source--A Preliminary Study,** NBSIR 86-3046 (April 1986).

Preliminary studies show that it may be possible 1) to determine the solar flux density incident on the earth's atmosphere using a simple algorithm with an uncertainty less than 8 percent, 2) to overcome a deteriorating accuracy in atmospheric loss calculations by using a "tipping curve" measurement, and 3) to reduce starshape correction factor uncertainty by using an equivalent solar diameter.
[Contact: William C. Daywitt, (303) 497-3720]

Microwave and Millimeter-Wave Metrology

Released for Publication

Daywitt, W.C., **A Simple Technique for Investigating Defects in Coaxial Connectors.**

A technique being studied that uses swept-frequency automatic network analyzer (ANA) data for investigating electrical defects in coaxial connectors is described. The technique is useful to connector and ANA manufacturers and to engineers interested in determining connector characteristics for error analyses. A simplified theory is presented, and the technique illustrated by applying it to perturbations caused by the center conductor gap in a 7-mm connector pair.
[Contact: William C. Daywitt, (303) 497-3720]

Engen, G.F., **In Search of a More Realistic Accuracy Statement for Microwave Metrology.**

The concept of "measurement accuracy" is fundamental to all of metrology. Given two different techniques for measuring the same parameter, an evaluation of their respective accuracies typically plays a major role in an assessment of their relative merit.

Historically, the accuracy achieved by the microwave metrologist has been limited by detector performance, hardware imperfections, and connector problems. Today, the effect of hardware imperfections has been largely eliminated by more complete modeling. Moreover, the performance of the detection systems has been improved to the point where, in many cases, the nonideal behavior of connectors is the major error source. Although important refinements in connectors have also been realized, it is quite possible that these have not kept pace with the other developments.

In any case, it is useful to pose the following question: Assume a measurement system which, apart from being fitted with connectors typical of those in general use, is otherwise perfect. How much measurement accuracy can one realistically claim for it?
[Contact: Cletus A. Hoer, (303) 497-3705]

Microwave & Millimeter-Wave (cont'd.)

Juroshek, J.R., **A Study Into Measurements of Connector Repeatability Using Highly Reflecting Loads.**

This paper investigates the repeatability of measurements of reflection coefficient, Γ, of highly reflecting devices with changes in the radio-frequency (rf) connector joint. In this analysis, the changes in the connector joint are due to the disconnecting and reconnecting of the connector pair. It is shown that many of the measurement discrepancies observed in actual practice can be explained with a simple connector model. The paper shows that the sensitivity of measuring rf connector changes can be enhanced by using highly reflecting loads. The changes in Γ due to changes in resistance or reactance can be four times greater for highly reflecting devices $(|\Gamma| \approx 1)$, as compared to nonreflecting devices $(|\Gamma| \approx 0)$. Experiments on two devices with 14-mm connectors are described, to compare with theory. The basic principles described in this paper should be beneficial to designers of connectors who need to detect small changes in connector parameters, and to designers of calibration standards who need to be concerned with small connector imperfections that contribute a major part of the measurement uncertainty.
[Contact: John R. Juroshek, (303) 497-5362]

Optical Fiber Metrology

Released for Publication

Day, G.W., and Franzen, D.L., Editors, **Technical Digest, Symposium on Optical Fiber Measurements, 1986.**

This digest contains summaries of 34 papers presented at the Symposium on Optical Fiber Measurements, held September 9-10, 1986 at the National Bureau of Standards, Boulder, Colorado.
[Contact: Gordon W. Day, (303) 497-5204]

Recently Published

Day, G.W., and Etzel, S.M., **Annealing of Bend-Induced Birefringence in Fiber Current Sensors,** Technical Digest of the 5th International Conference on Integrated Optics and Optical Fiber Communication, Venice, Italy, October 1-4, 1985, pp. 871-874.

The bend-induced linear birefringence in coils of single-mode optical fiber has been greatly reduced by annealing. This should allow the construction of electric current sensors that are much more compact and potentially more sensitive than previously possible.
[Contact: Gordon W. Day, (303) 497-5204]

Yang, S., and Gallawa, R.L., **A Comparison of Three Bandwidth Measurement Techniques for Multimode Optical Fibers,** IEEE Transactions on Instrumentation and Measurement, Vol. IM-35, No. 2, pp. 187-194 (June 1986).

This paper presents the results of an experiment to compare three distinct methods of measuring the bandwidth of a telecommunication-grade, multimode optical fiber. The three methods are: 1) the time-domain method, 2) the frequency-domain method, and 3) the pulse spectrum analysis method. We find good agreement between the frequency- domain method and the pulse spectrum analysis method, but the time-domain method yields results that are lower than the other two for the cases we considered.
[Contact: Robert L. Gallawa, (303) 497-3761]

Electro-Optic Metrology

Recently Published

Young, M., **Low-Cost LCD Video Display for Optical Processing,** Applied Optics, Vol. 25, No. 7, pp. 1024-1026 (April 1, 1986).

In this paper, I show that a liquid gate and low-pass filter are needed to use a

Electro-Optic Metrology (cont'd.)

new LCD video monitor effectively in a coherent-processing system, and I demonstrate the results of some simple spatial-filtering experiments.
[Contact: Matt Young, (303) 497-3223, -5342]

Complex Testing

Released for Publication

Stenbakken, G.N., and Souders, T.M., **Test Point Selection and Testability Measures Via QR Factorization of Linear Models**, paper given at the 29th Midwest Symposium on Circuits and Systems, Lincoln, Nebraska, August 10-12, 1986; to be published in IEEE Transactions on Instrumentation and Measurement.

An efficient algorithm is presented for selecting test points for use in applications such as calibration and fault diagnosis of electronic networks. The algorithm, based on factorization of the circuit sensitivity matrix by a technique known as QR factorization, minimizes the prediction or estimation errors which result from random measurement error. A definition of testability based on the concept of minimum estimation error is also introduced. Practical examples are given.
[Contact: Gerard N. Stenbakken, (301) 975-2440]

Other Fast Signal Topics

Recently Published

Cromar, M.W., Clark, A.F., and Fickett, F.R., **Flux Limit of Cosmic-Ray Magnetic Monopoles From a Multiply Discriminating Superconductive Detector**, Physical Review Letters, Vol. 56, No. 24, pp. 2561-2563 (June 16, 1986).

A multiply discriminating, three-loop superconducting monopole detector was operated for one year. During this period, 8523 hours of data were accumulated. The sensing area averaged over solid angle for trajectories passing through a loop was 178 cm^2. Including double coincidence events from trajectories passing through the shield but not through a loop, the total sensing area averaged over solid angle was 1195 cm^2. No candidate monopole events were observed, leading to an upper limit on the flux of cosmic ray magnetic monopoles of 5.0×10^{-12} cm^{-2} sr^{-1} s^{-1} with a 90% confidence level.
[Contact: Michael W. Cromar, (303) 497-5375]

Duffield, C.L., Moreland, J., and Fickett, F.R., **Problems with Cryogenic Operation of Piezoelectric Bending Elements**, Review of Scientific Instruments, Vol. 57, pp. 990-992 (May 1986).

Piezoelectric bimorphs constructed from lead titanate-zirconate (PZT) ceramic bonded to a brass sheet have been tested at cryogenic temperatures to determine their suitability for use in a low-temperature micropositioner. Experimental data are presented on bimorph sensitivity (displacement per volt) as a function of the number of temperature cycles. Results indicate that bimorphs of this type cannot be calibrated because of irreversible changes in the bending characteristics that occur while cycling from room temperature to 4 K.
[Contact: John Moreland, (303) 497-3641]

Young, M., **Scratch-and-Dig Standard Revisited**, Applied Optics, Vol. 25, No. 12, pp. 1922-1928 (June 15, 1986).

The scratch standard (MIL-O-13830A) is a cosmetic standard that is effected by a visual comparison with a set of secondary standards that are in turn evaluated by comparison with a set of master standards. Both manufacture and certification of the secondary standards are somewhat unreliable. This paper shows that they can be classified according to the relative power scattered at a relatively small angle and describes experiments with etched gratings that have the

Other Fast Signal Topics (cont'd.)

appearance of scratches but diffract light into a broad peak between 5 and 10 degrees off the axis of the incident beam. Some prototypes have been classified both by comparison with the master standards and by a photoelectric measurement; agreement between the two methods is good. Such gratings, used as the secondary standards, should display less intersample variation than scribed or other artifacts. The paper concludes by presenting evidence that the original primary standards have been stable over a long time.
[Contact: Matt Young, (303) 497-3223, -5342]

ELECTRICAL SYSTEMS

Power Systems Metrology

Released for Publication

Fenimore, C., **The Artificial Boundary Integral Method (ABIM): Flow Into an Aperture.**

Using a boundary integral, one may approximate certain irrotational, effectively incompressible, steady flows into an aperture. Here, a three-dimensional flow is estimated with a small computation. The flow boundary is a plane wall with an opening. The artificial boundary is the hole on which the outflow is an unknown function of position; the outflow may be approximated from measurements by a deconvolution. Three spaces of computational elements are considered and evaluated. The domain of the flow is the upper half-space in the upstream region for which the Green's function is known. The flow is approximated by reconvolution. This investigation was stimulated by the need to characterize the airflow into an ion counter.
[Contact: Ronald B. McKnight, (301) 975-2428]

Kelley, E.F., and Hebner, R.E., **Electro-Optic Field Measurement at a Needle Tip and Streamer Initiation in Nitrobenzene,** to be published in the Conference Record of the 1986 Conference on Electrical Insulation and Dielectric Phenomena, Wilmington, Delaware, November 2-6, 1986.

Kerr-effect electro-optic observations of the impulse field are made in the vicinity of the tip of a needle-sphere electrode geometry. Distortions from the Laplacian field indicate charge injection from the tip along a narrow channel prior to streamer initiation. Estimates reveal that charge densities on the order of 100 $\mu C/cm^3$ exist in the channel. An order of magnitude calculation suggests that sufficient energy is deposited in the channel to cause vaporization of the liquid due to joule heating. The streamer will initiate where the charge injection channel touches the electrode.
[Contact: Edward F. Kelley, (301) 975-2424]

Oldham, N.M., Laug, O.B., and Waltrip, B.C., **Digitally-Synthesized Power Calibration Source,** Summary to be published in CPEM 86 Digest, 1986 Conference on Precision Electromagnetic Measurements, NBS, Gaithersburg, Maryland, June 23-27, 1986. Full-length versions of papers presented at CPEM 86 are to be published in a special (CPEM 86 Proceedings) issue of the IEEE Transactions on Instrumentation and Measurement.

A digitally synthesized source of "phantom" power for calibrating electrical power and energy meters is described. Independent sources of voltage, current, and phase angle are programmable between 0 and 240 V, 0 and 5 A, and 0 and 360 deg, respectively. The accuracy of the active and reactive power is estimated to be within ±100 ppm of the full scale apparent power (volt-amperes).
[Contact: N. Michael Oldham, (301) 975-2408]

Petersons, O., and Mehta, S.P., **An Active High Voltage Divider and Phase**

Power Systems Metrology (cont'd.)

Shifter, Summary to be published in CPEM 86 Digest, 1986 Conference on Precision Electromagnetic Measurements, NBS, Gaithersburg, Maryland, June 23-27, 1986. Full-length versions of papers presented at CPEM 86 are to be published in a special (CPEM 86 Proceedings) issue of the IEEE Transactions on Instrumentation and Measurement.

An instrument combining an active high-voltage divider and a phase shifter designed to yield small phase angle uncertainties within 20 microradians is described. It is based on a circuit employing a feedback amplifier and a controlled source. The presence of the controlled source greatly reduces the potential of dynamic instabilities of the feedback loop and essentially eliminates the errors associated with the finite gain of the amplifier. Design and construction details and test results of accuracy evaluation are presented.
[Contact: Oskars Petersons, (301) 975-2400]

Van Brunt, R.J., **Common Parameterizations of Electron Transport, Collision Cross Section, and Dielectric Strength Data for Binary Gas Mixtures.**

Previously used parameterizations of dielectric strengths (electrical breakdown data) for gas mixtures in terms of electron collision and transport parameters are reviewed. A new method of fitting experimental data on dielectric strengths for binary electronegative gas mixtures is proposed based upon the principal assumption that the electron kinetic energy distributions in the gas are maxwellian. The method provides physical insight into such behavior as pressure-dependent or pressure-independent synergisms, and is useful in checking the consistency between dielectric strength data and available information on electron transport and ionization, attachment, and momentum-transfer collision cross sections. The method is applied here to the mixtures SF_6/N_2, $CC\ell_2F_2/N_2$, and $SF_6/CC\ell_2F_2$.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Recently Published

McKnight, R.H., **Discussion of Paper 85 WM 115-1, "A Fast Response Impulse Voltage Measuring System for Testing of Gas Insulated Substations Equipment,"** IEEE Transactions on Power Delivery, PWRD-1, No. 3, p. 47 (July 1986).

This is a discussion of a technical paper presented at the winter meeting of the Power Engineering Society, IEEE. It questions some of the author's assumptions and references further applications of the measurement method described.
[Contact: Ronald H. McKnight, (301) 975-2431]

Pulse Power Metrology

Recently Published

McKnight, R.H., Fenimore, C., and Lagnese, J., **The Use of Deconvolution Methods in Characterizing Electrical Sensors,** Proceedings of the Fifth IEEE Pulsed Power Conference, Crystal City, Virginia, June 10-12, 1985 (published by Institute of Electrical and Electronic Engineers, Inc., 345 East 47th Street, New York, NY 10017, May 1986), pp. 176-178.

Deconvolution methods have been applied to measurements made with different electrical sensors including resistive and capacitive dividers. Deconvolved and directly measured waveforms have been compared with good results.
[Contact: Ronald H. McKnight, (301) 975-3431]

Superconductors

Released for Publication

Benson, R.G., Goldfarb, R.B., and

Superconductors (cont'd.)

Pittmann, E.S., **Quench Circuit for Electronic Instruments Used with Superconducting Magnets.**

A multifunction circuit is described that protects instruments connected or coupled to a superconducting magnet in the event of a quench (reversion from superconducting) to normal state on the part of the magnet).
[Contact: Ronald B. Goldfarb, (303) 497-3650]

Ekin, J.W., **Effect of Irregularity in Filament Cross Sectional Area ("Sausaging") on Electric-Field Vs. Current Characteristics of NbTi Superconductors.**

Measurements of a correlation between filament irregularity ("sausaging"), and the shape of a superconductor's electric-field-versus-current (E-I) characteristic are reported. The shape of the E-I characteristic is quantified in terms of the resistive transition parameter n, defined by $E \alpha I^n$. Low values of n indicate significant filament irregularity. It is proposed that the parameter n could be used as a valuable index of filament quality in evaluating different superconductors for practical applications. A model is also suggested to explain this effect in terms of a locally depressed filament critical-current density, which forces current to transfer across the normal-matrix material into neighboring filaments.

Also reported is the relationship between n and the statistical distribution of filament diameters measured for the NbTi superconductors studied. This relationship may be useful as a quick method of estimating the extent of sausaging in practical multifilamentary NbTi superconductors from measurements of n.
[Contact: John W. Ekin, (303) 497-5448]

Recently Published

Dube, W.P., and Goodrich, L.F., **Quench Detector Circuit for Superconductor Testing**, Review of Scientific Instruments, Vol. 57, No. 4, pp. 680-682 (April 1986).

A quench detector is a device that interrupts the flow of current through a superconductor in the event the superconductor reverts to the normal, resistive state. This new design has adjustable filtering and sensitivity. The input is well isolated from the output, eliminating any possible ground loop through the detector. It also has excellent noise immunity.
[Contact: Loren F. Goodrich, (303) 497-3143]

Fickett, F.R., **Research on Practical Superconductors at NBS**, ATB Metallurgie, Vol. 25, No. 4 (Proceedings of the Benelux Metallurgy Conference on Superconductors, Brussels, Belgium, May 8-9, 1985), pp. 265-271.

The National Bureau of Standards is engaged in a number of research programs which have as their goals the evaluation of various properties of practical superconductors related to their application in large-magnetic systems. The ability to have standard data, standard tests, and standard materials for evaluating the primary properties of superconductors and related measurement systems is essential if international commerce in these complicated conductors is to develop and grow. The NBS work has concentrated on measurement of critical current, critical field, ac losses, and properties of the copper normally used as a stabilizing material. Many parameters must be considered in these investigations. An overview of these research efforts and a selection of recent results are presented. Particular emphasis is given to work performed in cooperation with the International Copper Research Association (INCRA) on properties of oxygen-free copper.
[Contact: Frederick R. Fickett, (303) 497-3785]

Moreland, J., Ekin, J.W., and Goodrich,

Superconductors (cont'd.)

L.F., **Electron Tunneling into Superconducting Filaments: Depth Profiling the Energy Gap of NbTi Filaments in High-Field Magnet Wires**, Advances in Cryogenic Engineering Materials, Vol. 32, R. P. Reed and A. F. Clark, Eds. (Plenum Publishing Corporation, New York, NY, 1986), pp. 1101-1108.

Squeezable electron tunneling (SET) junctions consisting of superconducting NbTi filaments (extracted from magnet wires) and sputtered Nb thin-film counter electrodes were used to determine the energy gap at the surface of the filaments. The current versus voltage curves of junctions immersed in liquid helium at 4 K were measured for a series of filaments taken from the same wire. Each filament had been etched to remove a surface layer of varying thickness so that the energy gap could be determined as a function of depth into the surface of an average filament. It was found that some manufacturing processes yield filaments having surface layers with reduced energy gaps of 0.4 meV compared to measured interior bulk values ranging from 1.2 to 1.3 meV.
[Contact: John Moreland, (303) 497-3641]

Magnetic Materials and Measurements

Released for Publication

Capobianco, T.E., **Field Mapping and Performance Characterization of Commercial Eddy Current Probes.**

Variations in the sensitivity of commercial eddy current probes are common, and this fact can cause reliability problems for those using eddy current inspection techniques. The National Bureau of Standards is conducting research to characterize eddy current probe performance. We have developed a unique capability to map the near magnetic field of these probes; results are presented comparing field maps to measurements of electrical and other performance parameters. We show that the magnetic field intensity per unit of excitation current has a direct relationship to the strength of the probe response to a simulated defect (for this study, electrical-discharge-machined notches) when corrections for probe/coil misalignments are made. Performance tests are reported which can account for coil misalignments as well as other factors affecting the strength of the defect response. The inclusion of these tests in a proposed military standard for eddy current probe characterization is also discussed.
[Contact: Thomas E. Capobianco, (303) 497-3141]

Capobianco, T.E., and Yu, K., **The Effect of Pickup Coil Spacing on Differential Eddy Current Probe Sensitivity.**

We report the results of an experiment investigating the effect of pickup coil spacing on differential probe sensitivity. The probe configuration for these experiments consists of an air-core excitation coil surrounding two air-core pickup coils. All three coils have vertical axes with respect to the flat plate test piece. Measurements were taken for three different pickup coil spacings on an aluminum test piece with four electrical discharge machined notches. The effect of pickup coil unbalance on probe response is also reported.
[Contact: Thomas E. Capobianco, (303) 497-3141]

Goldfarb, R.B., and Bussey, H.E., **Method for Measuring Complex Permeability at Radio Frequencies.**

An established method for measuring complex radio-frequency permeability is based on the change in inductance and resistance of a coaxial transmission line upon insertion of a sample toroid. It is not necessary to wind coils on the toroid or to correct for geometric demagnetization factors. The use of modern commercial impedance analyzers,

Magnetic Materials (cont'd.)

as described in this paper, makes measurements from 1 kHz to 1 GHz particularly easy, fast, and accurate.
[Contact: Ronald B. Goldfarb, (303) 497-3650]

Recently Published

Capobianco, T.E., Fickett, F.R., and Moulder, J.C., **Mapping of Eddy Current Probe Fields**, Review of Progress in Quantitative Nondestructive Evaluation, Vol. 5A, Chap. 3, Sec. A (Plenum Publishing Corp., New York, NY), pp. 705-711.

The magnetic fields produced by four different eddy current probes were mapped in the near field with very small (0.43-mm) diameter inductive magnetic field sensors. The four eddy current probes included two nominally identical, absolute, air-core probes; an absolute ferrite-core probe; a reflection probe with an air-core excitation coil; and two counterwound ferrite-core pickup coils. Measured fields for the air-core probes are compared with values calculated from the theory of Dodd and Deeds. All measurements were performed at 10 kHz; for the ferrite core probe, the field intensity was also measured from 1 kHz to 100 kHz using conventional methods.
[Contact: Thomas E. Capobianco, (303) 497-3141]

Heinrich, B., Cochran, J.F., Myrtle, K., Lonzarich, G., and Goldfarb, R.B., **Ferromagnetic Resonance at 9.55 and 23.9 GHz in the Weak Ferromagnet Ni_3Al**, Journal of Magnetism and Magnetic Materials, Vol. 54-57, pp. 1011-1012 (1986).

Ferromagnetic resonance (FMR) at microwave frequencies of 9.55 and 23.895 GHz has been measured in the archetypal weak itinerant ferromagnet Ni_3Al in the temperature range from 4 to 60 K. The observed FMR lines exhibited a strong Dysonian asymmetry and were well described over the whole temperature range by Maxwell's equations that included eddy currents, and by the Landau-Lifshitz (L-L) equation of motion including either Gilbert or L-L damping terms. At 4 K, the best fits were obtained using slightly angular dependent relaxation rates of 2.4×10^8 s^{-1} for saturation magnetization, M_s, along [111] and 2.0×10^8 s^{-1} for M_s along [100], and using a spectroscopic splitting factor g(Gilbert) = 2.2 ± 0.01 or g(L-L) = 2.14 ± 0.01.
[Contact: Ronald B. Goldfarb, (303) 497-3650]

ELECTROMAGNETIC INTERFERENCE

Radiated Electromagnetic Interference

Released for Publication

Bensema, W.D., Koepke, G.H., and Medley, H.W., **Handbook for NBS Multisensor Automated EM Field Measurement System**, to be published as NBSIR 86-3056.

A system is described that monitors and collects electromagnetic (EM) field strength information at five (optionally 10) locations simultaneously. The system has two modes of operation: 1) for sampling EM fields that are stationary for times of the order of 200 ms, and 2) for sampling changing EM fields with a system resolution of 10 μs. Sensing elements for Mode 1 consist of three electrically short orthogonal dipoles mounted together, single dipole elements, or small loop antennas. Each element feeds a separate data input channel for a total of 15 (optionally 30) channels. Radio-frequency energy is converted to dc by a diode detector at each dipole. Mode 2 sensors are diode detectors driven by broadband antennas. Real-time system data processing includes calculation of field strength based on probe calibrations and processing of resultant data to satisfy measurement goals.
[Contact: William D. Bensema, (303) 497-3465]

Radiated EMI (cont'd.)

Jesch, R.L., **A Survey of Triaxial and Mode-Stirred Techniques for Measuring the Shielding Effectiveness of Connectors and Cables**, to be published as NBSIR 86-3060.

This report is the result of an extensive literature search conducted in the field of connectors and cables and the problem dealing with radio-frequency leakage characteristics and the ability to measure the shielding effectiveness of these connectors and cables. It reviews two measurement techniques for determining the shielding effectiveness: the triaxial test technique that has been used for over 20 years and the mode-stirred test technique that recently has started to gain in popularity. From this survey, certain inferences are drawn about these techniques in terms of device configuration, frequency range, and ease of measurement and are presented in chart form for comparative purposes.
[Contact: Ramon L. Jesch, (303) 497-3496]

Randa, J., and Kanda, M., **A Lattice Approach to Volumes Irradiated by Unknown Sources**, to be published as NBS Technical Note 1303.

We suggest an approach to the characterization of electromagnetic environments irradiated by unknown sources. The approach is based on the numerical solution of Maxwell's equations subject to the constraints imposed by the measured values of the field at a small number of measurement points and by boundary conditions. A thorough examination is presented of two methods for the numerical solution. The examples attempted demonstrate the approach, but reveal that neither technique is fully successful. Possible future directions are suggested.

[A paper based on the contents of this Technical Note is scheduled for presentation at the Seventh Symposium and Technical Exhibition on EMC (Zurich, Switzerland, March 1987) under the title "A Lattice Approach to Environments Irradiated by Unknown Sources" and will appear in the proceedings of that Symposium. A second paper based on this material has been submitted to the IEEE Transactions on Electromagnetic Compatibility with the title "A New Approach to Volumes Irradiated by Unknown Sources.]
[Contact: James P. Randa, (303) 497-3150]

Wilson, P.F., and Ma, M.T., **Techniques for Measuring the Shielding Effectiveness of Materials**, to be published in the Proceedings of the 7th International EMC Symposium and Exhibition, Zurich, Switzerland, March 1987. [A more complete version appeared as NBS Technical Note 1095 (May 1986).]

Four methods for measuring the shielding effectiveness of materials under various conditions are considered. Coaxial transmission line holders and a time-domain system are used to simulate plane-wave shielding performance. The dual transverse electromagnetic (TEM) cell and an apertured TEM cell in a reverberating chamber are used to investigate near-field shielding capability. Both theoretical and experimental results are discussed.
[Contact: Perry F. Wilson, (303) 497-3842]

Recently Published

Crawford, M.L., and Koepke, G.H., **Design, Evaluation, and Use of a Reverberation Chamber for Performing Electromagnetic Susceptibility/Vulnerability Measurements**, NBS Technical Note 1092 (April 1986).

This report presents the results of work at the National Bureau of Standards to evaluate, document, develop (when necessary) and describe the methodology for performing radiated susceptibility/vulnerability measurements using a reverberation chamber. The report describes the reverberation chamber theory of

Radiated EMI (cont'd.)

operation, construction, evaluation, functional operation, and use for performing immunity measurements. It includes an estimate of measurement uncertainties derived empirically from test results and from comparisons with anechoic chamber measurements. Finally, it discusses the limitations and advantages of the measurement technique to assist potential users in determining the applicability of this technique to their electromagnetic compatibility measurement needs.
[Contact: Myron L. Crawford, (303) 497-5497]

Crawford, M.L., and Koepke, G.H., **Electromagnetic Radiation Test Facilities - Evaluation of Reverberation Chambers Located at NSWC, Dahlgren, VA,** NBSIR 86-3051 (June 1986).

This report describes measurement procedures and results obtained from evaluating the reverberation chamber facilities located at the Naval Surface Weapons Center, Dahlgren, Virginia. Two chambers were tested referred to as 1) the half chamber, and 2) the full chamber. The facilities were developed by the NSWC for use in measuring and analyzing the electromagnetic susceptibility/vulnerability of weapon systems and the shielding effectiveness of enclosures and shielding materials. A brief description of each facility is given, including the instrumentation used for performing the evaluation and calibration of the facilities by the National Bureau of Standards. Measurements described include: 1) evaluation of the voltage standing wave ratios of the chamber's transmitting and receiving antennas; 2) measurement of the chamber's insertion loss or coupling efficiency versus frequency; 3) measurement of the effectiveness of the chamber tuners; 4) determination of the electric-field uniformity in the chamber's test zones versus frequency; 5) determination of the absolute amplitude calibration of the test electric fields in the chambers, based upon received power measurements of the reference antenna and calibrated dipole probe antenna measurements; and 6) comparison of the response of reference equipment under test to test fields established inside the NSWC reverberation chambers and the NBS reverberation chamber. These results can then be compared to anechoic chamber results. Conclusions given indicate that the NSWC chambers can be used at frequencies down to approximately 150 MHz. Estimates are given of the measurement uncertainties derived empirically from the test results.
[Contact: Myron L. Crawford, (303) 497-5497]

Crawford, M.L., and Koepke, G.H., **Performing EM Susceptibility/Vulnerability Measurements Using a Reverberation Chamber,** EMC EXPO 86, International Conference on Electromagnetic Compatibility, Washington, D.C., June 16-19, 1986, pp. T28.7-T28.13.

This paper discusses the design, evaluation, and use of a reverberation chamber for performing electromagnetic susceptibility (EMS) measurements of electronic equipment. Included are brief descriptions of the test procedures, application advantages and limitations, some EMS test results, intrepretation of test results relative to free-space test methods, and an estimate of measurement uncertainties.
[Contact: Myron L. Crawford, (303) 497-5497]

Friday, D.S., **Methodology for Statistical Control of the Anechoic Chamber Field Generation System,** NBSIR 85-3033 (January 1986).

The microwave anechoic chamber in question is an NBS laboratory facility in which standard plane-wave electromagnetic fields are generated. This chamber enables specialized measurements and electromagnetic interference/electromagnetic compatibility tests to be conducted on antennas and other devices. This paper is concerned with methodology

Radiated EMI (cont'd.)

for assuring that the standard field patterns generated in the NBS and similar chambers are repeatable. Procedures are proposed for developing a data base from measurements obtained by placing the system, which generates the fields, in certain relevant reference configurations. Methodology is presented for developing statistical control charts to monitor both the location and the scale parameters of these data over time.
[Contact: Dennis S. Friday, (303) 497-5395]

Hill, D.A., **Out-of-Band Response of a Coax-to-Waveguide Adapter,** IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-28, No. 3, pp. 156-158 (August 1986).

The input impedance and transmission coefficients of a coax-to-waveguide adapter are analyzed for out-of-band frequencies. Numerical results are shown for an S-band adapter for frequencies from 2 to 10 GHz. The above-band response is frequency sensitive because of the presence of higher-order propagating modes in the waveguide.
[Contact: David A. Hill, (303) 497-3472]

Hill, D.A., and Francis, M.H., **Out-of-Band Response of Antenna Arrays,** NBSIR 86-3047 (June 1986).

The response of antenna arrays to out-of-band frequencies has been analyzed using the effective aperture approach. An average value of effective aperture can be obtained by averaging out the incidence angle and the polarization of the incident field. Far-field patterns have also been calculated by treating the array element excitations as random variables. The randomness in the element excitations causes a decrease in directivity and an increase in sidelobe level. Out-of-band measurements of reflection coefficient and near-field response have been made on two large slotted-waveguide arrays for frequencies from 2 to 18 GHz. Both arrays are narrow band, attributable to the large impedance mismatch at out-of-band frequencies.
[Contact: David A. Hill, (303) 497-3472]

Wilson, P.F., and Ma, M.T., **Simple, Approximate Expressions for Higher-Order Modes and Resonances in TEM Cells,** IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-28, No. 3, pp. 125-130 (August 1986).

Simple, approximate expressions for determining the cutoff frequencies of the first few higher-order modes and the associated resonances in transverse electromagnetic (TEM) cells are presented. Both symmetric and asymmetric cells are discussed with examples.
[Contact: Perry F. Wilson, (303) 497-3842]

Wilson, P.F., and Ma, M.T., **A Study of Techniques for Measuring the Electromagnetic Shielding Effectiveness of Materials,** NBS Technical Note 1095 (May 1986).

Shielding effectiveness relates to a material's ability to reduce the transmission of propagating fields in order electromagnetically to isolate one region from another. Because a complex material's shielding capability is difficult to predict, it often must be measured. A number of measurement approaches are studied including the use of a shielded room, coaxial transmission line holders, time-domain signals, the dual transverse electromagnetic (TEM) cell, and an apertured TEM cell in a reverberation chamber. In each case, we consider the system's frequency range, test sample requirements, test field types, dynamic range, time required, analytical background, and present data taken on a common set of materials.
[Contact: Perry F. Wilson, (303) 497-3842]

Conducted Electromagnetic Interference

Conducted EMI (cont'd.)

Released for Publication

Martzloff, F.D., and Key, T.S., **A Consensus on Powering and Grounding Sensitive Electronic Equipment**, to be published in the Proceedings of the IEEE/IAS Conference, Denver, Colorado, September 29-October 3, 1986.

As sensitive electronic processing systems proliferate, concern with the quality of power supplied to these systems increases. Efforts to alleviate perceived power supply problems have sometimes been misguided and have led to violations of the National Electrical Code. A new IEEE Working Group has been formed to prepare a guide document, which the paper describes while inviting participation from the engineering community.
[Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., and Levinson, L.M., **Surge Protective Devices and Zinc Oxide Varistor Technology**, chapter of book on Electronic Ceramics (provisional title), to be published by Marcel Dekker, Inc., New York, New York.

A tutorial description of surge protective devices, applications, and requirements, comparing the three basic technologies: crowbars, varistors, and avalanche diodes. The varistor material is described in detail from the electronic ceramics point of view. A reference listing includes 30 items.
[Contact: Francois D. Martzloff, (301) 975-2409]

ADDITIONAL INFORMATION

Lists of Publications

Gibson, K.A., Page, J.M., and Miller, C.K.S., **A Bibliography of the NBS Electromagnetic Fields Division Publications**, NBSIR 85-3040 (February 1986).

This bibliography lists publications of the National Bureau of Standards' Electromagnetic Fields Division for the period from January 1984 through September 1985, with selected earlier publications from the Division's predecessor organizations.
[Contact: Kathryn A. Gibson, (303) 497-3132]

Kline, K.E., and DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NBS Publications**, NBSIR 86-3048 (June 1986).

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NBS in the period from January 1970 through December 1985. A few earlier references that are directly related to the present work of the Division are included.
[Contact: Kathryn E. Kline, (303) 497-3678]

Palla, J.C., and Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NBS Electrosystems Division Publications, NBS List of Publications 94** (January 1987).

This bibliography covers publications of the Electrosystems Division, Center for Electronics and Electrical Engineering, NBS, and of its predecessor sections for the period January 1963 to January 1987. A brief description of the Division's technical program is given in the introduction.
[Contact: Jenny C. Palla, (301) 975-2220]

Walters, E.J., **Semiconductor Measurement Technology: A Bibliography of NBS Publications for the Years 1962-1986**, NBSIR 87-3522 (February 1987).

This bibliography contains reports of work performed at the National Bureau of Standards in the field of Semiconductor Measurement Technology in the period from 1962 through December 1986. An index by topic area and a list of authors are provided.
[Contact: E. Jane Walters, (301) 975-2050]

1987 CEEE CALENDAR

July 28-30 (Vail, CO)

Short Course on Optical Fiber Measurements. This course is sponsored by the National Bureau of Standards and the University of Colorado with the cooperation of members of industry who serve as faculty together with staff from the Electromagnetic Technology and Electromagnetic Fields Divisions. The course is intended for scientists and engineers involved in optical fiber characterization and emphasizes concepts, techniques, and apparatus used in measuring engineering parameters of telecommunications-grade fibers.

The following major topic areas are addressed: optics for communications, emphasizing geometric optics concepts; fiber properties and parameters; index-profile measurements; fiber bandwidth measurements in the frequency and time domains; fiber attenuation measurements; connector and splice losses; optical time-domain reflectometry concepts and applications; single-mode fibers; statistics and error analyses, measurement uncertainties; and fibers for sensors. [Contact: Office of Conference Services, University of Colorado (303) 492-8630; Robert L. Gallawa (303) 497-3761; or Matt Young (303) 497-3223]

September 14-16 (Research Triangle Park, NC)

VLSI and GaAs Packaging Workshop. This Workshop is co-sponsored by the Components, Hybrids, and Manufacturing Technology Society of IEEE and NBS; attendees are expected to be knowledgeable in the field and to participate in discussions. Topic areas include: VLSI and wafer scale package design (characterization and implementation, cost and performance driven solutions); package thermal design (characteristics, results, and issues); package interconnection options (wire bonding, TAB, flip chip, or optical); GaAs IC packaging (high speed packaging considerations); package electrical issues (reduction of parasitics and improvements in electrical performances); integrating package design (from die to system, including assembly and test issues); VLSI package materials advancements; die-attach solutions for large chips; new failure mechanisms in VLSI packaging. [Contact: George G. Harman, (301) 975-2097]

September 22-25 (Boulder, CO)

Noise Measurement Seminar. This four-day course is presented and hosted by the Electromagnetic Fields Division in cooperation with representatives from industry and the NBS Time and Frequency Division. It is intended for practicing noise metrologists and technical managers responsible for systems in which accurate measurements of thermal and phase noise are important. Attendees will learn the most important precautions to take in making accurate noise measurements and will receive a set of notes that are suitable for use in solving precision noise measurement problems. Course topics include reference thermal noise sources; thermal noise measuring systems and techniques; phase noise; and the problems of measuring thermal noise in passive components, amplifiers, and communication systems.

The course design combines formal lectures on theory presented by NBS staff and industry experts with demonstrations in NBS laboratories and demonstrations of commercial equipment. A special feature of the Seminar is the opportunity each day for attendees to share their experiences in solving specific problems or their insights on practical noise measurement issues through short presentations to the assembled group. Time is scheduled for group discussions of these presentations and other topics raised by the Seminar.
[Contact: Sunchana Perera (303) 497-3546]

1987 CEEE Calendar (cont'd.)

September 23-25 (Gaithersburg, MD)

Workshop on the Role of Optics in Power System Electrical Measurements. This Workshop is sponsored by NBS, the Bonneville Power Administration (BPA), the Electric Power Research Institute (EPRI), and the Empire State Electric Energy Research Corporation (ESEERC) and is intended for research and development engineers in utilities and in companies that supply equipment to the utility industry. The objective of this workshop is to identify anticipated opportunities for improved measurement techniques that should arise as power systems individually and collectively evolve to meet the needs of the 1990s. Presentations will stress the design and testing of optical systems for 60-Hz voltage or current measurement; the interfacing of electronic or optical components with existing metering and control systems; opportunities for new measurement hardware resulting from increased automated control of power systems and of the testing of power system components; and optical techniques for the measurement of electric and magnetic fields in power systems or system components. The results of an NBS study evaluating optical techniques for power-system electrical measurements and carried out in agreement with BPA, EPRI, and ESEERC will be presented as an invited keynote. [Contact: Robert E. Hebner, (301) 975-2403]

October 26-28 (Boulder, CO)

Symposium on Optical Materials for High Power Lasers (Nineteenth Boulder Damage Symposium). This Symposium is cosponsored by the National Bureau of Standards, the American Society for Testing and Materials, the Air Force Office of Scientific Research, the Office of Naval Research, and the Defense Advanced Research Projects Agency and constitutes a principal forum for the exchange of information on the physics and technology of materials for high-power lasers.

Topics to be discussed include new materials, bulk damage phenomena, surface and thin-film damage, design considerations for high-power systems, and fundamental mechanisms of laser-induced damage. Proceedings of the Symposium will be published (Note: The collection of Symposium proceedings contains information on optics for all aspects of high-power/high-energy lasers, including environmental degradation, durability, fabrication, material growth and deposition processes, and testing). [Contact: Susie A. Rivera (303) 497-5342]

December 10-11 (Gaithersburg, MD)

Power Semiconductor Devices Workshop. This Workshop, sponsored jointly by IEEE and NBS, is intended to bring together for interactive participation those actively working in the field of power semiconductor devices. It will be held in conjunction with the 1987 IEEE International Electron Devices Meeting in Washington, DC. Four specific topic areas have been selected, based on the response to a questionnaire sent to over 200 power device researchers worldwide. They are: power and high voltage integrated circuits, discrete devices, device modeling, and packaging. Attendees are expected to be prepared to contribute to the development of responses to specific questions that arise in the context of the particular topic areas; a final schedule identifying the topic areas should be available at the end of October. [Contact: David L. Blackburn, (301) 975-2053]

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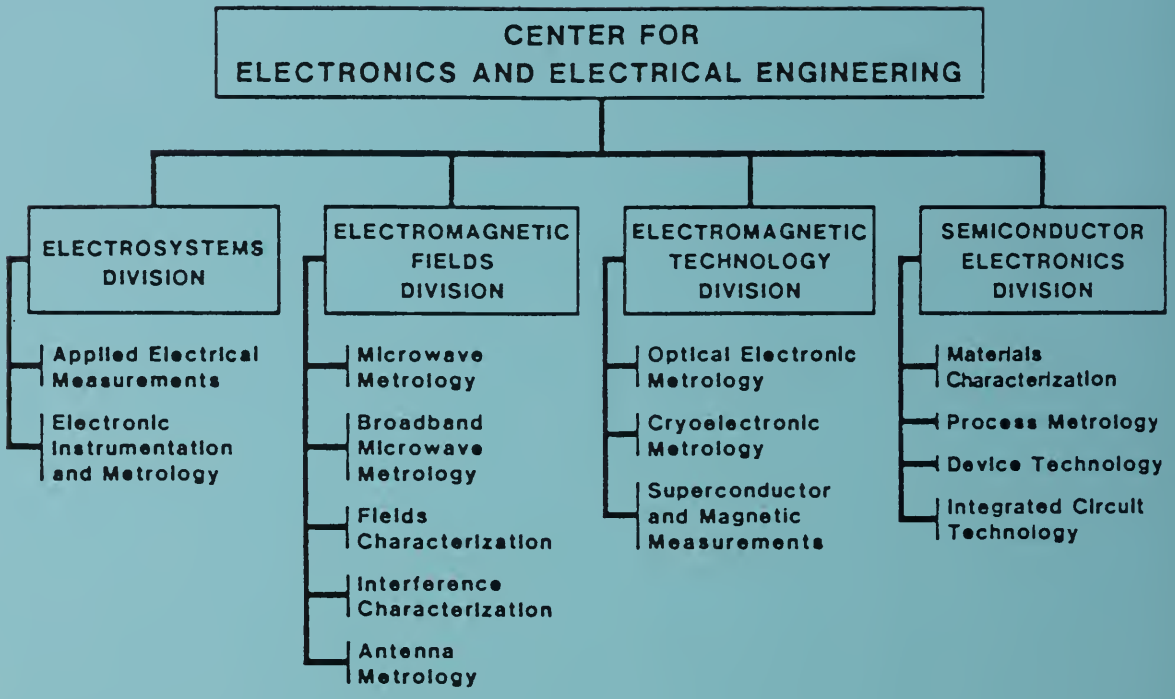

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